

# Visuocognitive Fluency Facilitating ECG Interpretation with Visual Metaphors and Expressive Tags

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**The acquisition of data for medical diagnosis may be regarded as reliable and accurate, however visual representations of these data may cause significant cognitive load to novice practitioners, or learners. ECG interpretation is a case in point. This paper introduces work in progress with regard to facilitating ECG interpretation through the use and testing of visual metaphors and expressive tags. Commonly used in domains such as visual advertising, comics, musical notation, performing arts and education, visual metaphors serve as a useful heuristic to present complex concepts. Testing the potential impact of visual metaphors and expressive tags on the accuracy of ECG interpretation is novel to ECG research. The visuocognitive principles introduced in this paper have the potential to make a positive contribution to HCI and information visualisation.**

*Keywords: visuocognition, visual metaphor, expressive tags, ECG interpretation*

## 1 INTRODUCTION

With the growth of computer technology in medical settings there is a potential increase of information overload for clinicians. In significantly busy work environments clinicians increasingly rely on computer representations of medical data who need accessible and effective HCI infovisualisations. Device recalls with usability problems are relatively common. For example, it was recently reported in User Experience Magazine that a device had to be recalled because image orientations of patients' left and right sides caused confusion and decision errors (Clark and Israelski, 2012). The visualisations were not abstract but pictorial. Conversely, abstract data output from reliable and sound devices are regularly used, yet due to their abstract visualisations information is difficult to interpret. In May 2017 the BBC reported that at least seven baby deaths at an NHS trust were deemed as avoidable. The coroner reported that the deaths related to

cardiotocographs (CTG) and a contributing factor to the errors related to CTG-interpretation (Buchanan, 2017) Life and death can hinge on effective visualisations (Bond et al., 2013). A similar device to the CTG, that is regularly used worldwide, with characteristically similar abstract output and which induces a significant cognitive load is the electrocardiogram (ECG), the misinterpretation of which has led to fatalities (Breen et al., 2014). The ECG is a complex time series graph with concomitant discrete and continuous data. Its representation of cardiac electrical activity is abstract, a biosignal, with high temporal resolution. Although ECG is predominantly temporal, the electrode positional 'viewpoints' and the graph deflections provide cues to some spatial information, but for novice clinicians this information is cognitively remote and difficult to interpret (Bond et al, 2014). It is widely reported that electrocardiology is difficult to teach and learn; its concepts are complex, (Cairns et al., 2016; Zeng et al., 2015) and its representations

are inaccessible. As such, this is a substantive and pragmatic human factors problem for clinicians (Bond et al., 2014).

## 2 HUMAN FACTORS AND ECG INTERPRETATION

ECG visual code manifests itself in twelve scattered graphs that do not correspond to the electrode 'viewpoints' thus rendering the information disparate and difficult to read. This difficulty is exacerbated when combinations of morphologies must be recognised, committed to memory, examined, and linked to cardiac pathologies to arrive at a diagnosis. Additionally, the deflections from the ECG baseline appear very similar and this lack of differentiation consequently contributes towards cognitive load and the difficulties of ECG interpretation.

Previous research shows that the use of conventional and novel visual metaphors can be a useful heuristic and a cognitive strategy that promotes cognition of complex information (Casakin, 2007; Bowdle and Gentner, 2005). Additionally, design researchers have shown that a prerequisite for cognitive fluency is the alignment of design to human visual perception (Ware, 2008). We use the term *visuocognitive* design to refer to infovisual design that aligns with neurocognitive features (such as metaphor comprehension and cognitive economy mechanisms) to achieve cognitive fluency. Visuocognitive design principles may add to the Vitruvian design requirements of durability, usability and beauty (Vitruvius, circa 30BC - 15 BC; Vande Moere and Purchase, 2005). It may be argued, therefore, that visuocognitive design, visual metaphors and 'expressive tags' (as this paper coins them) may facilitate a heuristic interpretation of the ECG. An expressive tag is a graphic mark or set of marks created to express certain qualities about a graphic object or symbol. They describe four qualities: condition, motion, movement and degree. Therefore, their role is to support the intended meaning of a visual metaphor and may reduce polysemic interpretations.

## 3. WORK IN PROGRESS

Our work includes the development of a repository of pictorial schematics for the representation of ECG data for the purposes of evaluation. Drawing on Peircean visual semiotics, the schematics will use iconic, symbolic and indexical means to connote intended meaning (Table 1). The temporal data

of the ECG will be spatialised over the cardiac landscape – the 'base-map' that constitutes level one of three. The second level will depict cardiac structures that have fixed positions over the base-map, and will be metaphorised using colour codes and shapes. The third level will depict unfixed cardiac pathologies and will employ visually metaphoric schematics supported by expressive tags. There will be different aspects to test. For example, the metaphoricity of a metaphor may be high or low depending on its novelty. A conventional metaphor is deeply lexicalised so little cognitive effort is needed to access its meaning (Mashal and Kasirer, 2012). However, a novel metaphor is not lexicalised, it cannot rely on previous knowledge and may need the aid of expressive tags to promote interpretation. The effect of the expressive tags needs to be investigated (Figure 1). The term 'lexicalised' is used generically here and this paper refers to the visual lexicon. As visual metaphors are different to verbal metaphors they are processed differently; pictorial information (semantic) is encoded through two neural pathways while verbal information is encoded through one route (Mashal and Kasirer, 2012). As top-down (cortical) neural processing can affect interpretation – for example, the activation of the precuneus in metaphor comprehension and semantic tasks (Mashal et al., 2014) – it is hypothesised that expressive tags will reduce polysemy, however, this hypothesis needs empirical investigation.

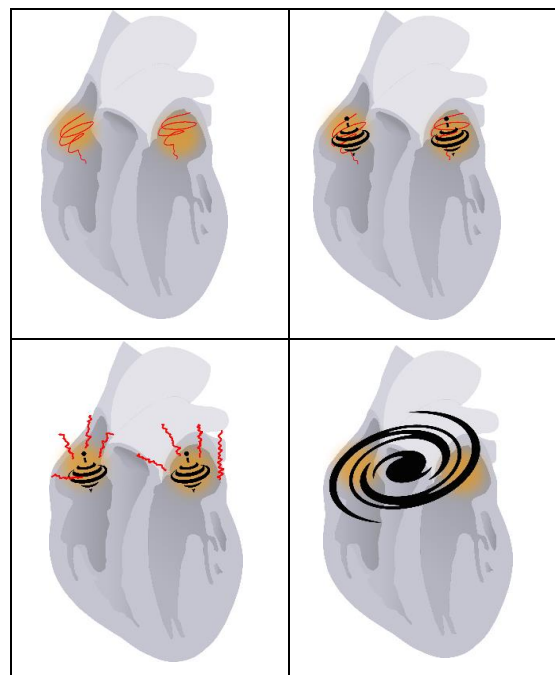


Figure 1: Options depicting Atrial Fibrillation.

**Table 1:** Pictorial-schematic elements and semiotic levels. The pink box draws attention to visual metaphors, expressive tags and intuitive tags and the modes used to show cardiac pathologies. These modes include: shape, size, colour-coding, motion, movement, condition, scale, context and knowledge cues.

Cardiac Elements	Position	Condition or Flow	Motion	Movement	Visual Metaphoricity	Expressive Tags	Intuitive Tags	
3 <b>Cardiac Pathologies</b>	Unfixed Locations	Condition of cardiac structures and the degree of pathology (Vis.metaphor & tags)	Ion activity, vector direction and speed, and escape	Arrhythmias, myocardia, valves,	Visual metaphorical representations through shape, size and colour-codes	<ul style="list-style-type: none"> <li>● Motion</li> <li>● Movement</li> <li>● Condition</li> <li>● Degree</li> </ul>	Expressive tags that have inherent intuitivity, based on context, cues, knowledge, & recognition	
2	<b>SA Node</b>	Fixed	Ion issues/block	None	None	Colour/Shape/Tag	YES	YES
	<b>AV Node</b>	Fixed	Ion issues/block	None	None	Colour/Shape/Tag	YES	YES
	<b>Paths &amp; BB</b>	Fixed	May block/Escape	None	None	Colour/Shape/Tag	YES	YES
	<b>Valves</b>	Fixed	May clamp or seize	None	Open / Close	Colour/Tag	YES	YES
1 <b>Cardiac Landscape</b>	Fixed Base	None at this level. (see level 3)	None	Although myocardia contract, this level represents a static base map	N/A	N/A	No, but cardiac landscape is intuitively recognisable	
Elements of Flow	<b>Ions</b>	Throughout conductive and contractile cardiomyocytes	Flow through cell sodium, potassium & Calcium channels.	AP moves through conductive cells. Propagation via contractile cells.	None. Motion is moving (unfixed). Movement is moving (fixed).	YES	YES	YES
	<b>Electrical Vectors</b>	Normally follow a fixed route. Normal average electrical axis: +35°	Normally via conduction pathways and cardiomyocytes. However, may escape	Variable speed and duration	None. Motion is moving (unfixed). Movement is moving (fixed).	YES	YES	YES
	<b>Blood</b>	Fluid. May pool in atria during atrial fibrillation.	Via main vessels. Via cardiac arteries & veins. Via atria & ventricles. Via valves	As ECG relates to electrical activity, flow of blood is not depicted.	As ECG relates to electrical activity, flow of blood is not depicted.	Ischaemia depicted at an indexical level.	N/A	N/A

**Mechanisms of Cognition**

Semiocognition may be facilitated through considered combinations of graphic containers, graphic space, graphic objects and colour codes. Visuocognition may be achieved through visual metaphors and expressive tags.

**Iconic (Level 1)**

This is the base and broadly iconic. Pictorially realistic and true to anatomical and topographical cardiac structure.

**Symbolic (Level 2)**

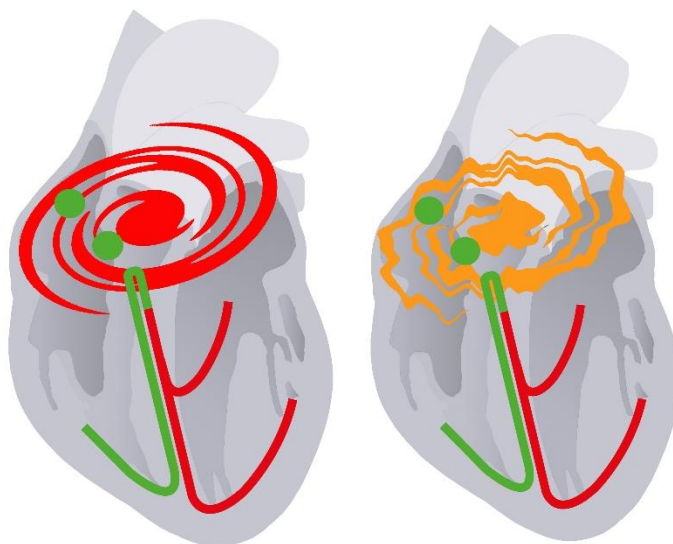
Broadly Symbolic using colour and shapes. May also be iconic and indexical, but with stylised abstraction. to reduce visual 'noise'.

**Indexical (Level 3)**

Broadly Indexical. Visual metaphors and expressive tags are used to describe and point to heart conditions.

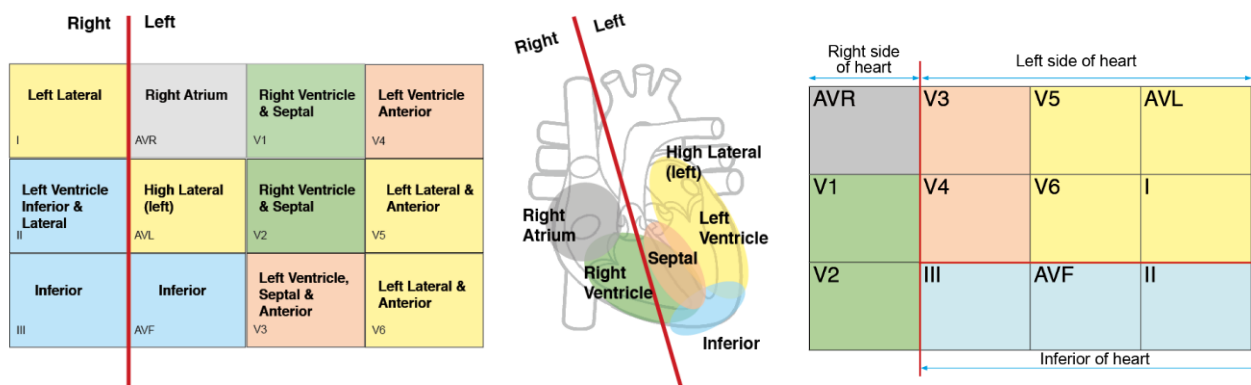
Expressive tags are like pictorial runes and can be metaphorical themselves as well as having a supportive role towards visual metaphors (Ojha, 2015). The metaphor for atrial fibrillation depicted in figure 2 is an example of this where the expressive tag (the swirl) is the metaphor. As expressive tags describe motion, movement and condition, it is probable that the right schematic achieves this more than the left schematic. The traffic-light colour codes are employed here too.

The accuracy of ECG interpretation and diagnosis is the ultimate goal of this research, thus the human factors and impact of visuocognition also need to be explored. This research makes the assumption that the technical facility to translate ECG code into accessible pictorial schematics will be in place, therefore the stimuli will be simulations.

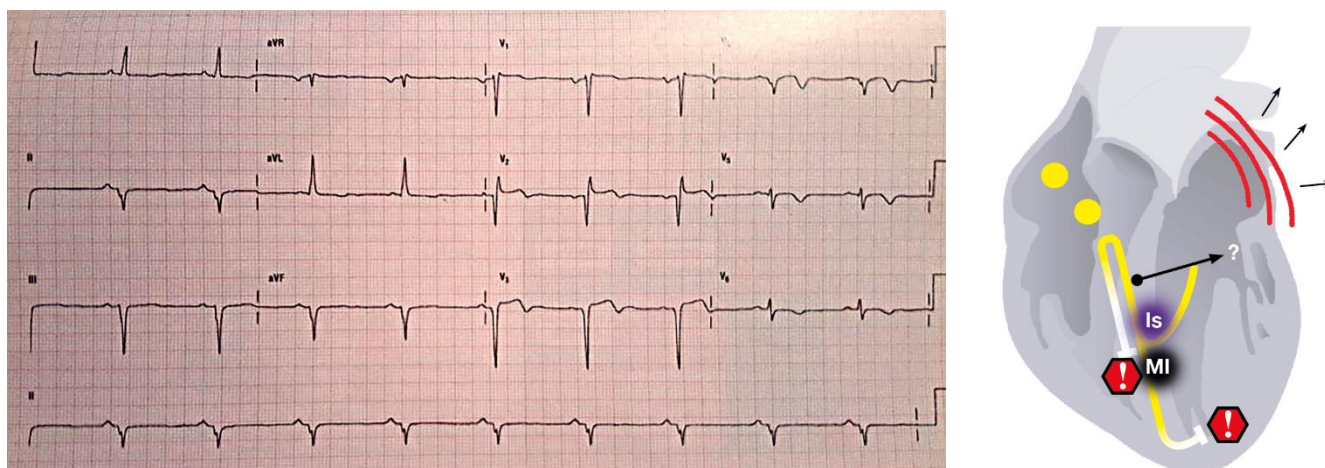


**Figure 2:** Atrial fibrillation with left bundle branch block. As atrial fibrillation involves repeated circular depolarisation of the atria plus the experience of rapid palpitations, the right depiction is preferable.





**Figure 3:** The central image divides the heart into right and left and labels its anatomical parts. The grid to the left represents a 12-lead ECG and, through colour coding, demonstrates that the twelve leads (or ‘views’) of the heart do not correspond to the coloured areas shown on the heart. The grid to the right is adjusted so that lead ‘views’ do correspond. For example, leads V1 and V2 ‘view’ the right ventricle (green area), therefore they are relocated to the anatomical position – the right side of the heart.



**Figure 4:** Morphologies such as elevated ST segments, flipped symmetrical T waves and poor R-R progression indicate the following pathologies depicted on the pictorial schematic: an anteroapical myocardial infarction (AMI), incomplete right bundle branch block (RBBB), left atrial enlargement (LAE), Ischaemia, and a left anterior hemiblock.

In summary, it is posited that learning electrocardiology induces cognitive load because of the following

- Lead ‘views’ do not correspond to 4x3 12-lead arrangement causing orientation issues.
- Difficulties rationalising the abstract characteristics of ECG code
- Visual similarities make differentiation of ECG anomalies difficult
- High temporal resolution and low spatial resolution make topographical orientation difficult.
- Reliance on memory rather than recognition contributes to cognitive load
- Accretions of ECG complexities evolved, absent of human factors

#### 4. CONCLUSION

Claims about the complexities of ECG are well known. However, this research taxonomises them adopting a human factors and visualisation approach to test visuocognitive solutions to the problems. As such, we believe this research is novel and has scope for further investigation.

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